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Internetworking: worldwide multicast of the Hamming Lectures for distance learning

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NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

INTERNETWORKING: WORLDWIDE
MULTICAST OF THE HAMMING LECTURES
FOR DISTANCE LEARNING

by

Tracey L. Emswiler

September 1995

Thesis Advisors: Don Brutzman
                                        Maxine Reneker

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13. ABSTRACT

The mission of the Naval Postgraduate School (NPS) is to educate, train and prepare officers for the 21st Century Navy (Austin, 1988). Distance learning, also known as distance education, remote learning or video teletraining, is defined as communication between an instructor and student via some form of telecommunications. Distance learning has the potential to enable dramatic improvements in training and education by providing remote access to high-quality presentations. There is also a potential to multiply training and education benefits, and to provide savings in travel and lost time expenses. This thesis investigates distance learning combined with a new technology known as the Multicast Backbone (MBone). It documents how Dr. Richard Hamming's course "Learning to Learn" was transmitted world-wide over the Internet's Multicast Backbone (MBone) for an entire quarter. This thesis proves that the MBone is an economically feasible approach that works. This is the first documented attempt to provide complete course coverage with world-wide scope for a full academic quarter using the MBone. Specific lessons learned are included in an MBone user's guide and recommendations for future work.

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INTERNETWORKING: WORLDWIDE MULTICAST OF THE
HAMMING LECTURES FOR DISTANCE LEARNING

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Submitted in partial fulfillment of the requirements for the degree of

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The mission of the Naval Postgraduate School (NPS) is to educate, train and prepare officers for the 21st Century Navy (Austin, 1988). Distance learning, also known as distance education, remote learning or video teletraining, is defined as communication between an instructor and student via some form of telecommunications. Distance learning has the potential to enable dramatic improvements in training and education by providing remote access to high-quality presentations. There is also a potential to multiply training and education benefits, and to provide savings in travel and lost time expenses.

This thesis investigates distance learning combined with a new technology known as the Multicast Backbone (MBone). It documents how Dr. Richard Hamming's course "Learning to Learn" was transmitted world-wide over the Internet's Multicast Backbone (MBone) for an entire quarter.

This thesis proves that the MBone is an economically feasible approach that works. This is the first documented attempt to provide complete course coverage with world-wide scope for a full academic quarter using the MBone. Specific lessons learned are included in an MBone user's guide and recommendations for future.

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I. INTRODUCTION

This thesis investigates various aspects of distance learning combined with a new Internet technology known as the Multicast Backbone (MBone). The research revolves around a case study that documents the learning points derived from a successful worldwide Multicast of Dr. Richard Hamming's course "Learning to Learn." This is the first documented attempt to provide complete course coverage for a full academic quarter using the MBone.

A. BACKGROUND

1. Distance Learning

Distance learning, also known as distance education, remote learning or videoteletraining, is defined as communication between an instructor and student via some form of telecommunications. It utilizes technology for teaching and learning situations in which students are geographically separated from educators, and both depend on electronic devices to communicate (Biggs 94). A draft Military Standard on the "Interoperability and Performance Standard for Video Teleconferencing" defines video teleconferencing (VTC) and video teletraining (VTT) as follows:

> Video teleconferencing is a two-way electronic form of communications that permits two or more people in different locations to engage in face-to-face audio and visual communication. Meetings, seminars, and conferences are conducted as if all participants are in the same room. Video teletraining (or distance learning) is the use of teleconferencing point-to-point or multipoint to provide interactive remote site training. (MIL-STD-188-331, 93)

Distance learning is the subject of much speculation. The Office of Naval Technology has conducted research in the field of distance learning with the goal of finding more cost-effective ways to train personnel who are geographically remote from training resources (Simpson, Pugh 91). In 1991, the Office of Naval Technology sponsored a six-month study involving 743 Navy students to investigate the effectiveness and user acceptance of live instruction (Simpson, Pugh 91). This study used videoteletraining technologies to deliver lecture-based training, with the overall goal of

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exploring technologically cost-effective ways to train personnel who are geographically separated from training resources.

This goal was reached by conducting an empirical study comparing training effectiveness and user acceptance of live instruction and six different alternative VTT technologies: multichannel two-way video with two-way audio, single channel two-way video with two-way audio, one-way video with two-way audio, one-way video with one-way audio, one-way video with intermittent two-way audio, and audiographics (Simpson, Pugh 91).

This study showed that several different forms of VTT technologies were effective, in terms of both student performance and student and instructor acceptance. The specific type of VTT technology did influence student performance and attitudes, but had a far smaller effect than student experience. The study also noted that the most successful VTT technologies were those allowing continuous two-way audio with either two-way or one-way video. And finally, student test performance was poorer with VTT systems that restricted remote students' ability to converse with or see the instructor (Simpson, Pugh 91).

One recommendation resulting from the project was that the Chief of Naval Education and Training (CNET) continue efforts to refine the CNET VTT network, as well as analyze the feasibility and cost-effectiveness of extending the architecture of the CNET VTT network, using VTT technologies such as one-way video with two-way audio and one-way video with one-way audio (Simpson, Pugh 91).

Taking VTT one step further, in 1992 the Office of Naval Technology sponsored another study to determine if VTT could be used to deliver hands-on training, as well (Simpson, Pugh 92). Up to this point, VTT had been used for lecture-based training only. The results of this project showed that VTT was effective for lecture, discussion, and hands-on demonstration portions of training, as indicated by the final examination, student course evaluations, and observations. The VTT classroom design was also effective for hands-on training. It could serve as a model for others designing VTT classrooms for hands-on training.

More recently, in 1993, the Navy Personnel and Research Development Center documented procedures for converting live instruction for VTT delivery. The intent was to make these procedures available to Navy trainers and others responsible for VTT delivery (Simpson 93).

The studies sponsored by the Office of Naval Technology and performed by the Navy Personnel Research and Development Center have all proven that VTT can be used to link students and instructor across great distances. There are alternative VTT technologies that vary greatly in cost, so the Navy must focus on selecting the proper and most cost-effective VTT technologies.

2. Multicast Backbone (MBone)

The Multicast Backbone (MBone) originated from experiments during the 1992 Internet Engineering Task Force (IETF) conferences in San Diego and Boston, in which live audio and video were transmitted around the world. The MBone currently links Unix workstations and has been called a 'virtual network' because it uses the physical Internet to support routing of Internet Protocol (IP) multicast packets (Casner 93). Multicasting is a function that allows conservation of network traffic because a sending site can ship audio and video packet streams that are replicated only once, even though receiving routers distribute the videoconference to multiple desktops (Wexler 93). For example, on a multicast network, a packet sent from machine A can be distributed to machines B, C, and D without the original packet having to be sent three times (Weiss 95).

Because a standard audio transmission uses about 64 Kilobits per second (Kbps), and a default video transmission takes approximately 128 Kbps, an average worldwide conference will take up to about 200 Kbps of bandwidth and could even go as high as the global limit of 500 Kbps. This is nearly one-third of a T1 line, which is 1.5 Megabits per second (Mbps) and is a common site-to-site link on the Internet today. Without the benefit of multicast, that T1 line can be completely utilized by just three conferencing sessions, not even taking into account other network uses such as electronic mail, file transfer and Web browsing. Multicast represents a huge savings when one considers the amount of bandwidth that is consumed by audio and video.

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B.   MOTIVATION

1.   What is the Importance of Distance Learning?

Any organization, (private industry, Government or military) faced with increasing costs and decreasing resources tends to push education and training down the priority list. Training programs may be eliminated. Educational institutions might even be forced to limit what is offered to students. In the United States today, many organizations are forced to do more with less. When it comes to education and training, distance learning provides an option that is economically attractive for accomplishing educational requirements.

The Navy possesses a wide geographic dispersal of home ports, fleet units, and Navy Reserve detachments. The costs associated with transporting Navy personnel to a few facilities for classroom training are great. These costs include transportation, travel expenses, and the travel time lost from duty. In spite of these factors, there is still a requirement to train Navy personnel who are geographically remote from training resources (Simpson, Pugh 92). Effective training of personnel is essential to achieve and maintain national security, as well as national strategic objectives.

Issues that have a negative effect on the ability of the Department of Defense (DoD) to accomplish that mission are personnel drawdowns, base closures, and reduced budgets. Effective training of personnel is essential. In fiscal year 1994, DoD allocated about $15 billion towards individual training and education (Biggs 94). Because the drawdowns have made it increasingly difficult to offer service members the opportunity to go on TAD, distance learning provides an economical and efficient solution. By importing an instructor via some form of telecommunication, a command can save on travel dollars per diem and, in most cases, registration fees.

In the Navy, at a time when deployment schedules have become restrictive, distance learning allows for increased flexibility for leaders. With online course work, the Navy can offer classes at any time of day. As more ships, commands, and individual units become connected to local-area networks (LANs) and wide-area networks (WANs),

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distance learning programs can be implemented, providing more economical avenues for training.

Does distance learning work? A variety of videoconferencing and distance learning technologies have received considerable attention in the DoD. Those studies previously mentioned all reached the same conclusion and made the same recommendation. That is, VTT in several different forms was effective in terms of both student performance and student and instructor acceptance. The studies also agree that the Chief of Naval Education and Training should support the use and continued study of VTT for educating Naval personnel (Simpson, Pugh 91).

Due to the fact that training needs for each military branch are different, difficulty arises when trying to plan, prepare and implement training. Understanding when an approach can and ought to be employed and what benefits will be received is crucial for successful implementation. The following scenarios are provided as a means of determining when distance learning technologies may be appropriate (Wright 93) :

- Population is dispersed and cannot be economically transported to a central training site.

- Students in a training group have diverse learning styles, skills, or proficiency.

- Delivery must be closely monitored for accuracy or interpretation.

- Students cannot be taken from job for extended periods due to mission requirements.

- Live training is cost prohibitive.

- The number of instructors with proper credentials is limited.

The Naval Postgraduate School (NPS) has several requirements and objectives in the area of distance learning. Off-campus education, technology refresher training of NPS graduates, and the ability to 'import' an instructor without the travel costs are some of these requirements (Steckler, Stewart 94).

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2. Why use the MBone?

The MBone is a part of the Internet that is used for audio and video teleconferencing. It is attractive in that it works and provides real value today. The MBone can bring expertise over long distances and multiply training benefits. The development of the Internet has expanded the walls of the traditional classroom. Students today have access to a wealth of global information, such as remote libraries, discussion groups, and computer conferences. Students also can make connections with other students and with teachers around the world (Aoki, Goto 95).

The combination of MBone resources with the concept of distance learning provides students and teachers with the capability of physically seeing and talking to each other. Just imagine the value of live video brought directly from the space shuttle into the classroom. Think about watching scientists study the ocean floor in the Monterey Bay and then being able to ask them questions directly, all via a computer. These capabilities are currently available.

Another expected benefit of using the MBone be the ability to archive audio and video on the Internet for digital video retrieval on demand. This future work will literally put educators and their lectures online and open up even more possibilities for distance learning. It will actually bring the classroom to the student anytime it is necessary. This is an extremely promising area for future work.

C. THESIS SUMMARY

This thesis is broken into the following chapters. Chapter II discusses related work in the fields of distance learning and the MBone. Chapter III provides the reader with an understanding of the MBone. Chapter IV describes the principal problems investigated in this thesis. Chapter V documents the distance learning case study involving the multicast of Dr. Hamming's class. Chapter VI summarizes the conclusions drawn from the case study, as well as recommendations for future work. In addition, several appendices are provided as supplements to the thesis. Appendix A is a User's Guide for accessing and using the MBone tools. Appendix B is a list of acronyms used throughout this thesis. Appendix C is a glossary of terms used in this thesis.

II. RELATED WORK

A. INTRODUCTION

This chapter discusses recent work that has been conducted in the fields of distance learning, the multicast backbone, and network connectivity for educational purposes. A short summary of each study is provided to explain the study's topic and how it relates to this thesis.

B. GAMBRINO: MBONE USABILITY

This thesis looks at the choices managers face when dealing with video teleconferencing (Gambrino 94). In particular, this thesis focuses on the perceived effectiveness of the MBone from a manager's perspective. Data for this research is based on an NPS study with the Monterey Bay Aquarium Research Institute's (MBARI) Internet conference experiment to compare the MBone versus face-to-face viewer perceptions of the different communication media. This study concluded that the MBone should not be used in communication situations involving emotional conflict, bargaining, and negotiation. The MBone is recommended for use in communication situations involving uncertainty reduction.

C. MICE PROJECT: VIDEO ARCHIVING IN EUROPE

The Multimedia Integrated Conferencing for Europe (MICE) project has been piloting MBone technology in Europe. In order to make the Hamming lecture series accessible to the much wider audience in Europe, the author provided copies of the lecture series video tapes to the major MICE National Support Centers in Europe, which then arranged for a remulticast of the Hamming lectures. A further research endeavor includes digitizing video for media retrieval on demand. More information about the MICE center can found at *http://www.cs.ucl.ac.uk/mice/mice.html* (Handley)

D. BIGELOW: INTERNETWORKING K-12 SCHOOLS

This thesis documents the planning, design, and implementation of a regional, wide area network connecting K-12 schools, research institutions, libraries, and institutions of

higher education throughout the Monterey Bay area of California's central coast. It can be found online at *http://www.stl.nps.navy.mil/~rjbigelo/thesis.html* (Bigelow 95).

E. STECKLER AND STEWART: DISTANCE LEARNING PLAN

The study examined requirements and design for the development and implementation of a videoteletraining (VTT) system for 25 Defense Finance and Accounting Service (DFAS) centers. The study focuses on basic and technological issues regarding all aspects of VTT as they apply to DoD, including current technology, evolving VTT hardware and software capabilities, and compression algorithm standards (Steckler, Stewart 94).

F. RETTINGER: DESKTOP VIDEO CONFERENCING

This study looks at the various aspects of desktop video conferencing. This research involves an experiment that utilizes the technology of the MBone to deliver a week-long seminar to participants throughout North Carolina. Topics also include the human factors issues with desktop videoconferencing and the interactive seminar demonstration (Rettinger 95).

G. DISTANCE LEARNING EFFORTS

As the Internet connects universities and colleges all over the world, educational applications are widely discussed among educators and researchers. The biggest advantage of the Internet is its international connectivity (Aoki, Goto 95). Regionally, there is a research project called Monterey BayNet which has been internetworking K-12 schools, colleges, universities, museums, libraries, government agencies, and research institutions in two California counties (Brutzman 95). The network design provides access to live or archived media using a variety of bandwidth rates (Brutzman 95). This ongoing network project gives teachers and students full access to the Internet and all the information that the World-Wide Web (WWW) has to offer.

H. SIGGRAPH '95 "MBone UNPLUGGED"

At a week-long graphics conference held at the Los Angeles Convention Center, a team of NPS students (including this author) designed and built a mobile MBone cart that used wireless networking technology in order to broadcast the events at SIGGRAPH.

This experiment provided a more in-depth look into the details of setting up a network that involves MBone transmissions. It gave the team an opportunity to test the limits of wireless communications and raised a series of questions that have the potential to further the research and technology of the MBone (Brutzman, Emswiler 95).

III. MULTICAST BACKBONE (MBone)

A.   INTRODUCTION

Over the last decade, the personal computer (PC) has evolved from a stand-alone personal productivity device to a widely-connected information tool. Networked PCs are becoming the center of business communication. PCs are already used to send faxes and electronic mail (e-mail), to share databases and automate workflow, and even to hold long-distance meetings using unicast videoconferencing tools. The resulting boon to productivity is spurring strong demand for further PC-based communication applications. The drive to improve communication via PC is a major force behind technology developments in the 1990s. We expect that eventual availability of MBone tools will be a major event in PC evolution.

The author has read articles that state the Multicast Backbone (MBone) is "not yet ready for prime time," and has attended the Internet World conference, where a multimedia expert stated the MBone could not be used for distance learning. As a member of the NPS Information Infrastructure Research Group (IIRG), the author studied and documented the viability and impact of distance learning over the MBone. The goal of this work is to show that the MBone can be used for academically useful distance learning. Some technical considerations must be explained first.

The MBone provides many-to-many network delivery services for applications such as videoconferencing and audio where several hosts need to communicate simultaneously. Because the MBone utilizes the Internet, there are no enforced restrictions on its use. Although this capability is impressive, it does have drawbacks. For example, individuals with inadequate equipment or improper training can bring down entire networks. If the MBone is to be considered a shared medium for distance learning, there must be an understanding as to the impacts and implications of doing so. This work demonstrates that effective global learning using the MBone is feasible.

Multicasting has existed for several years on local area networks such as Ethernet and Fiber Distributed Data Interface (FDDI). However, with IP multicast addressing at

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the network layer, group communication can be established across the Internet (Macedonia, Brutzman 94). Because multicasting functionality has not been integrated into many routers, the MBone is layered over the Internet using multicast routers (called mrouters), which typically are dedicated workstation-class machines.

The MBone provides near-real-time audio and video delivery. Some time delays or communication failures can be expected because of network congestion. Packets of data that carry the audio and video signals across the network may become lost during transmission, causing communication dropout. These losses are a function of overall Internet capacity and are largely independent of the number of people subscribing to a given MBone session.

B.   CONSIDERATIONS

    1.   Setting up an MBone Environment

The MBone has been called a virtual network because it shares the same physical medium as the Internet. It uses a "tunneling" scheme to forward multicast packets among the islands of MBone subnets through Internet IP routers that (typically) do not support IP multicast (Macedonia, Brutzman 94).

To receive multicast packets on a LAN, a system administrator will need to configure an mrouter. This can be either a single workstation on a LAN, or a host dedicated as a parallel mrouter (Macedonia, Brutzman 94). Another option is to take an old, unused workstation and reconfigure it as an mrouter. This process requires adding a second Ethernet card to the workstation so that this mrouter can act independently and in parallel with the standard IP router (Macedonia, Brutzman 94). The Naval Postgraduate School uses both approaches. Downloading the application software tools is the next step.

This discussion about connecting a site to the MBone has been brief. For a complete set of instructions, the reader should look at the Frequently Asked Questions (FAQ). The MBone FAQ is a good source for system administrators wishing to establish an mrouter on site. It provides detailed information and instructions for downloading

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software tools and for ensuring that multicast-compatible kernels are available for target workstations. The FAQ can be found online at *ftp://venera.isi.edu/MBone/faq.txt*.

2.   **What is Needed to Participate on the MBone?**

a.   *Hardware Requirements*

No special hardware is required to receive video on the MBone. Decoding and display are all done in software using an X-window display. The data rate is typically 25 Kbps to 128 Kbps. Transmitting video requires a workstation with a frame-capture board and camera, typically a camcorder with a video output or built-in camera. Several different boards are supported, including Sun's SunVideo, SGI's IndigoVideo, and the Sony NEWS frame capture board.

To receive audio, a machine must be audio equipped such as the SunSparc10 with an audio box, some Hewlett-Packard workstations, the SGI Indy and SGI Indigo. On most architectures, no hardware other than a microphone is required - sound I/O is via the built-in audio hardware.

b.   *Software Requirements*

Software applications for use on the MBone have been developed by researchers on a voluntary basis. At this time the tools are free of charge and need only be downloaded and placed on a Unix workstation.

c.   *Other Requirements*

(1) Good lighting: A desk lamp is significantly better than office lighting for improving image quality, especially in otherwise low light conditions with inexpensive cameras.

(2) Video camera: If video is to be transmitted, a fixed focus camera that works well in well lit conditions is fine for the desktop. A video camera is more expensive, but performs better in lower light and has zoom capability. A camera is not required to receive or display video.

d.   *Associated Costs*

Taking time to learn how to connect to and use the MBone is what usually poses the greatest cost. It takes approximately one to three weeks for a

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network-knowledgeable person, working part-time, to establish the MBone at a new site (Macedonia, Brutzman 94). Depending on the number of users and the amount of MBone usage, there may also be a need for a dedicated MBone network administrator.

Equipment cost is often relatively low. An SGI entry-level workstation runs between \$15-\$20K. The cost of video cameras ranges from \$50 for a simple desktop version to \$2,000 for a high-powered piece of equipment. The MBone mailing lists publish up-to-date price listings on the latest equipment needed for communicating on the MBone.

Another equipment cost that must be considered is bandwidth. NPS runs the MBone tools on workstations connected via Ethernet (10 Mbps). The off-campus links are via T1 lines (1.5 Mbps). NPS researchers have found that bandwidth capacities lower than T1 are generally unsuitable for MBone video (Macedonia, Brutzman 94). Some users on specially configured networks have managed to make the tools work at 56 and 64 Kbps (Macedonia, Brutzman 94).

3. **Using the MBone Tools**

The following is a list of MBone applications available on the Unix workstations at the Naval Postgraduate School. Appendix A provides detailed instructions for using these tools.

(1) <u>Session Directory (*sd*)</u>: Session Directory is the tool used to manage MBone sessions. It displays available sessions and can be used to create new ones. Sessions will be announced in the session directory window. Clicking on a session name gives information about the session, such as time and date of transmission.

(2) <u>Network Video (*nv*)</u> tool: Network Video is used to transmit and receive slow-frame-rate video. It has a default bandwidth of 128 Kbps, which provides a typical frame rate of three to five frames per second. When a session that involves video communications is selected from the session directory, a control panel appears. The panel consists of a menu bar, a box to show iconic versions of active video streams, and some number of additional panels. *nv* allows the user to specify various options. In most cases, the assigned defaults are adequate.

(3) Visual Audio Tool (*vat*) version 2.4: Visual Audio Tool is used for audio teleconferences. When a session that involves audio communications is selected from the session directory, the *vat* window appears. It is not necessary to speak in order to participate in a conference. In fact, the normal etiquette is to wait until the speaker has finished and has opened questions to the floor or to the Internet, before speaking. Using *vat* requires a certain amount of prudence to avoid accidental transmissions during conference sessions.

(4) Video Conference (*vic*): Video Conference is an experimental video conferencing tool for transmitting video over an IP Multicast network. The main *vic* window provides an abbreviated summary of all sources that are actively transmitting video to the conference address. If no one is transmitting video to the session, the text "No Network Sources" is displayed in the window.

(5) Shared whiteboard (*wb*) tool: Shared whiteboard can be used as a shared white board drawing surface and it can be used to export and view postscript files. Speakers can make their slides available as postscript files during a conference session. The camera can be directed at the speaker while the slides are viewed via the whiteboard facility.

C.   SUMMARY

It isn't every day that someone says to you, "Here is a multimedia television station that you can use to broadcast from your desktop to the world" (Macedonia, Brutzman 94). The MBone has changed the way people work and interact on the net.

Today the MBone is used by thousands of researchers in collaborative efforts to further technology and other research efforts. Created in 1992 for group communications among universities and research labs, the MBone has approximately 1,800 nodes, roughly the same number that the Internet had in 1990.

Many events are broadcast over the MBone, including NASA Select's coverage of shuttle missions and audio sessions of the House and Senate. The November 18, 1994 Rolling Stones concert was one the largest MBone events. There is even a "radio-station"

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called Radio Free Vat, where any MBone participant can sign up for spots to play music "on the air."

It is the author's opinion that the most significant of all uses of the MBone is the ability to provide distance learning. There is a potential to multiply training and education benefits, and to provide savings in travel and lost time expenses. More important, the MBone is a convenient, accessible way to educate personnel all over the world.

IV. PROBLEM STATEMENT

A. INTRODUCTION

The focus of this thesis is to investigate what is required to produce an ongoing educational event over the Multicast Backbone (MBone). The MBone is a new technology, however, several questions pertain. Can the MBone sustain the bandwidth constraints and uncertainties associated with the Internet? Can the MBone be used for distance learning? If so, how is it done?

When transmitting audio and video, it is important to achieve near-real-time quality. This quality is difficult to achieve due to the high amount of bandwidth associated with the two. Private networks use high-speed dedicated links, whereas the Internet is a shared internetwork with many thousands of users doing many different things at any given time (Muirden 95). Today, there are over forty commercial products for conducting real-time audio and video over the Internet. Two of the most widely used systems are the MBone tools and CU-SeeMe (Muirden 95).

B. NAVAL POSTGRADUATE SCHOOL (NPS) GOALS

The following mission statement is from the Naval Postgraduate School's World Wide Web home page.

> The mission of the Naval Postgraduate School is to enhance the security of the United States of America through graduate and professional education programs focusing on the unique needs of the military officer. These programs are sustained by research and advanced studies directed towards the needs of the Navy and DoD. Our goals are to increase the combat effectiveness of the armed forces of the U.S. and its allies, and to contribute to fundamental scientific, engineering, policy, and operational advances that support the Navy, DoD, and other national security establishments (Taylor 95).

NPS has a vision of being the world leader in defense-related graduate education and research by the year 2000. The intent is to provide the future leaders of the armed

services with the technical, analytical, and managerial skills needed to create and sustain efficient, cost-effective, and fully combat-ready military forces (Taylor 95).

NPS education will be recognized as a key ingredient in the career development of military officers, as a vital enhancement of their war fighting capabilities, as a critical step in preparing for joint and combined assignments, and as a key element leading to high level leadership positions (Taylor 95).

Currently, personnel are assigned to NPS for an average tour of two years. Unfortunately, there is neither enough money nor time to send every officer to NPS. One of the five NPS guiding principles is to invest in the education, training, technology, and facilities needed to fulfill the mission. Because military and DoD personnel are scattered all around the world, it is difficult for NPS to educate those people who are unable to attend formal training. One potential solution to this problem is the increasing network connectivity within DoD and military institutions. If they do not have the technology today, then they are likely to in the future. With network connectivity comes the capability to institute a distance learning program. Although the Navy has conducted previous research in the area of video teletraining, what makes this research different is a new technical capability called the MBone.

C.   THE MULTICAST BACKBONE (MBone)

The MBone was developed as a tool that allows researchers to communicate using audio and video over the Internet. Until a few years ago, people thought that the Internet could not support the transmission of live audio and video. Although the robustness of the Internet Protocol (IP) leads people to believe that the Internet cannot be broken, it does have its limits. High-bandwidth applications such as audio and video are pushing these limits to the extreme.

One common analogy is that the Internet is like a freeway. The more cars there are on the road, the longer it takes to get to work. Sometimes there are accidents or collisions, which can cause even greater delays. As more cars are built, more cars get on the freeway, causing even more congestion. Every time another car gets on a busy freeway, it causes others to slow down. When drivers have to slow down or are even

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forced to get off the freeway until another time, delays become unacceptable. Similarly, the Internet can take only so much traffic before quality of service becomes an issue. The more users are active on the Internet, the greater the chance that other users are affected. Therefore, the quality of service degrades.

Chapter V provides a detailed look at the MBone. Appendix A explains how to use the MBone tools.

D.   THE CASE STUDY

Using the MBone, an NPS course was transmitted live to the world three times a week. As discussed in Chapter I, audio and video take up a lot of bandwidth. Transferring huge amounts of bandwidth, such as the kind associated with digitized video and audio traffic, can bring most networking technology to a standstill. Thus, many open questions had to be addressed.

The use of audio and video on the Internet is increasing (Muirden 95). Today, most events on the MBone are localized or special one-shot events--perhaps for one day at a time or for a whole week. Because the Internet currently lacks the capacity for everyone to multicast everywhere simultaneously, coexisting with other users on the Internet using both audio and video on a regular production basis has not previously been attempted.

This case study consisted of broadcasting a total of 31 lectures from Dr. Richard Hamming's course "Learning to Learn" over an entire academic quarter. By conducting this study, the author attempted to prove that the MBone can sustain the impact of an ongoing event, and remote participants would receive Dr. Hamming's class on schedule.

This project presented two obstacles. The first is a technical issue. The Internet can handle only so much bandwidth before signal quality begins to degrade. The remote participants must be able to understand what the instructor is saying. When numerous users utilize the MBone, the Internet connections can become bogged down, producing terrible signal quality or maybe no signal at all.

The second obstacle deals with human issues relating to a shared resource. Global MBone bandwidth is estimated at only 500 Kbps. A site wishing to broadcast a special

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event might find itself limited by another site's existing event. To try to alleviate any problems that might occur, the author announced the plan to broadcast the course and the willingness to make schedule adjustments, when necessary. Chapter V describes the case study in detail.

E.   SUMMARY

The goal of this thesis was to prove that the MBone can sustain the bandwidth constraints and uncertainties associated with the Internet. Due to the large amounts of bandwidth consumed by audio and video, and the problems that exist with a shared network, it is difficult to achieve a signal quality that is acceptable enough for distance learning.

The case study demonstrated that distance learning over the Internet will work. The research in this thesis applies a new technical capability called the MBone to the Naval Postgraduate School goals of providing distance learning and can be utilized to expand the role of NPS in a much more economical way.

V. THE HAMMING MULTICAST

A.   INTRODUCTION

The purpose of this research was to test the MBone's ability to sustain an ongoing event for use in the field of distance learning. Live audio and video of a course taught at the Naval Postgraduate School (NPS) were sent to participants world-wide three times per week for a full academic quarter. The objective of this research was to "push back the envelope" regarding the kinds of programming that are possible on the MBone. The course was transmitted on a global channel to test the ability of transmitting for an extended period of time--in this case, for eleven weeks. The goal was to learn some new lessons and to then distribute both results and recommendations to the MBone community. This effort involved finding a location with suitable attributes for an MBone broadcast, providing network connectivity, installing and connecting necessary equipment, and finding an instructor who would agree to be part of an Internet first and was willing to be taped while lecturing to the world. This chapter describes how each of these efforts was accomplished and why certain decisions were made. It also provides detailed accounts of the problems that occurred.

B.   PRODUCTION REQUIREMENTS

The first step was finding a location to meet the network, electrical, and acoustical requirements. The room also needed to be large enough to hold a class of about 60-75 students. Initially, a number of locations on campus appeared to possess the physical characteristics necessary to broadcast a course over the MBone. They were the auditoriums in Glasgow and Ingersoll Halls, various classrooms in Spanagel Hall, and the newly constructed auditorium next to Melville Hall. However, numerous difficulties emerged.

The Glasgow auditorium (room 109) had an audio visual projection room and was large enough for the expected number of students. However, its acoustics were inadequate. The auditorium in Ingersoll (room 122) had an audio visual projection room, excellent acoustics, and enough room for about 100 students. However, Ingersoll 122 is

used for a number of conferences which hold a higher priority. If a scheduling conflict were to arise, the class would have to relocate for that period of time. Spanagel Hall had a number of rooms that were large enough and that had good acoustics, but none of them had audio visual capabilities. The equipment used for the multicast would have to be moved in and out of the classroom three times a week. This would take a lot more work and had a great potential for equipment problems to occur. The auditorium by Melville Hall had the best acoustics, excellent lighting conditions, would hold close to 100 students, and had an audio visual projection booth. However, it lacked network connections and equipment in the booth, and the building itself was still under construction and would not be finished by the beginning of quarter. After careful consideration of all options, the author chose the new auditorium by Melville Hall as the most suitable location.

The following section discusses the measures taken to prepare the auditorium to be an MBone distance learning environment.

1. Network Setup

The top priority was network connectivity. NPS employees, along with an outside contractor, installed a fiber to Ethernet adapter in the projection booth. The MBone tunnel was successfully configured to include the appropriate LAN, and it tested out satisfactorily.

2. Hardware/Software

A Silicon Graphics Inc. (SGI) Indy workstation was set up in the AV booth of the auditorium. The MBone software tools and an electronic mail tool were loaded on the Indy. Currently, there are no monitoring tools for the MBone. As a result, the only way to receive immediate feedback about the quality of a signal at some remote site is via e-mail. E-mail was monitored through a telnet window.

All classes were broadcast with audio and video. The announcement appeared in the Session Directory (*sd*) under "Hamming: Learning to Learn." This session was created at the beginning of the quarter and remained there until the end. The scope of the sessions was set to *ttl* = 127, global transmission. Video was transmitted using Network

Video (*nv*) for maximum compatibility with remote users. The bandwidth was kept at the default of 128 Kbps. Audio was transmitted using Visual Audio Tool (*vat*). The default audio input was changed from microphone mode to line-in mode. The gain level slider was adjusted as required during each lecture, and adjustments to the scope and bandwidth were made when scheduling conflicts arose.

Under the Menu button from *vat*, Lecture Mode was selected over the default Conference Mode because this was a noninteractive session, and Lecture Mode results in a better quality signal. The Silence Suppress was also turned off, allowing the transmitting site to keep the focus of the audio session and making it difficult for other sites to send audio on that session. The User's Guide for the MBone in Appendix A provides a more detailed description of the MBone software tools and setup selections.

3. Audio Visual Setup

The basic audio visual requirements are known: a standard video camera with a tripod, a TV monitor, and a VCR which was used to tape each lecture while it was being broadcast. Because the audio visual booth was in a separate room inside the auditorium, audio was provided using a wireless microphone given to the professor before each lecture. No attempt was made to include the MBone audience(s) in the audio portion of the lectures. Taking questions from the network required a sound system for the auditorium (so the NPS audience could hear the questions). Since this capability was not part of the research at the time, questions were taken via e-mail.

The professor's requirements were unknown. If computer-generated video were used, it would have to be scan-converted to NTSC (National Television Standards Committee). If traditional overhead slides were used, the best way to pipe them into the MBone would have to be determined. Another consideration was that video projection causes lighting problems if there are cameras in the room.

Once requirements were properly identified, personnel from the NPS AV department worked several hours to set up the equipment in the projection booth. After the first day of testing, the camera was inadvertently left on overnight. As a result, it overheated and failed. After the camera was replaced, all of the wiring had to be redone.

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Audio/video checks for both MBone and the VCR were then satisfactory. To prevent errors such as the one mentioned above, the following checklist, covering everything from the equipment to the building itself, was created:

(1) Room

    - Lights => All on except light above board & light in booth

    - Doors => Close auditorium doors when class begins

    - Lectern => Is it still there?

    - Markers/Erasers => Only black & red for maximum contrast

    - Close door to projection booth

    - Erase board after lecture

    - Lock doors when finished

(2) Video/Audio Equipment

    - Power button on top of camera

    - Lens cap off

    - Turn on TV

    - Turn on VCR

    - Put in new tape/cue tape

        -- Ensure only two lectures/tape

        -- Label tapes with title, lecture number and date

    - Set record speed to SP for best quality

    - Start recording ~ 3 minutes prior to actual start

    - Turn on wireless microphone and test

(3) Workstation

    - Login

    - Open session directory (*sd*) via console

    - Open Hamming session from *sd* menu

    - Set audio panel MENU to the following:

          -- no silence suppress

          -- lecture mode

       - Change the microphone icon to digital input

       - Select "Keep Audio" to ensure this is active session

       - Video panel: Verify bandwidth: 128 Kbps

    (4) Important Phone Numbers List Handy

    (5) Network Monitoring Tools

       - Etherview =>   /usr/etc/etherview -g

C.   COURSE INFORMATION

    Dr. Richard Hamming accepted the request to participate in this world-wide experiment. Dr. Hamming received a Ph.D. in Mathematics from the University of Illinois in 1942. He worked at Los Alamos from 1945 to 1946, at Bell Laboratories from 1946 to 1976, served three years at Princeton University as an Adjunct Professor of Statistics, and joined the Naval Postgraduate School in 1976. Dr. Hamming is a past president of the Association for Computing Machinery (ACM) and recipient of the Turing Prize of the ACM. He is both namesake and a recipient of the IEEE R.W. Hamming medal and has received a large variety of other awards. Dr. Hamming is the author of numerous papers and books.

    The name of his course is "The Art of Doing Science and Engineering: Learning to Learn." It is often referred to as "Hamming on Hamming" due to the fact that Dr. Hamming's work began or greatly influenced many of the subject areas covered in his course. Topics include: foundations of the digital (discrete) revolution, foundations of computer hardware/software/applications; limits of computer applications and artificial intelligence (AI); N-dimensional space, coding theory, error correcting codes, information theory, digital filters, simulation, fiber optics, computer-aided instruction (CAI),

mathematics, quantum mechanics, creativity, experts, unreliable data, and systems engineering. Dr. Hamming has written about his course:

> I will examine, criticize and display styles of thinking. To illustrate the points of style I will often use technical knowledge that most of you know. . . . You should regard this as a course that complements the many technical courses you have learned. Some of the things I will talk about are things that I believe you ought to know but which simply do not fit into courses in the standard curriculum. . . The course is concerned with 'style,' and almost by definition style cannot be taught in the normal manner by using words. I can only approach the topic through particular examples, which I hope are well within your grasp, though the examples come mainly from my 30 years in the mathematics department of the Research Division of the Bell Telephone Laboratories, (before it was broken up). It also comes from years of study of the work of others. (Hamming 95)

D.   RESULTS

1.   Findings

Classes were held Tuesdays and Thursdays from 1210-1300 Pacific (1910-2000 GMT) and Fridays from 1410-1500 Pacific (2110-2200 GMT). A total of 31 lectures were broadcast between March 28 and June 6, 1995. Observations were made and are documented in the following sections. The findings are broken up into these categories: Camera Work, Audio Issues, Scheduling Issues, Statistical Information, Room Issues, and Miscellaneous Findings.

a.   Camera Work

The first day of class, the author met with Dr. Hamming to go over procedures for the multicast. Dr. Hamming warned that he walked around quite a bit, so camera work might be tricky. He also requested that the students in the classroom be included in the broadcast as well. Dr. Hamming felt the remote viewers might become bored with seeing only his face. He also requested there be a clock and a lectern in the room.

During these broadcasts, the author observed the lectures from the video camera, video monitor, and SGI workstation inside the AV booth of the auditorium.

Being on the receiving end of an MBone broadcast allowed the author to make some interesting observations. First, traditional video taping, with constant movement of the camera, is not appropriate for MBone transmissions. Because of the slow frame rates associated with MBone transmissions, a lot of camera movement will generally cause image loss, causing the viewer to miss out on certain elements of a presentation. As the speaker moves around, it works best to pan back and hold the image of the instructor as he/she moves around the room. Sometimes it is easier for remote viewers to understand a lecture if close-ups of the speaker are filmed as he/she is standing at a lectern or in one position for awhile. An alternative is having a second camera on hand. The ability to switch between cameras opens up a new angle for producing a more professional-looking show.

When video taping information, equations, etc., from a chalkboard or dry eraser board, it is best to put the camera on the information and hold it for at least three to four seconds. Holding the camera steady gives the image a chance to fully update and provides remote viewers a chance to focus on the information. Moving the camera back and forth only results in lost data.

Another observation was that red and black markers were the only ones that could be seen on the MBone. The camera had a difficult time focusing on blue ones.

b. *Scheduling Issues*

The "Hamming" lecture series was announced prior to the first broadcast. Because MBone audio and video sessions can consume a large amount of bandwidth, users should attempt to minimize the effect of MBone traffic on other users of the network. For example, for an entire week in April 1995, the World-Wide Web (WWW) conference in Germany was also being multicast over the MBone. As a result, the Hamming classes were broadcast live only in the local area with a $ttl = 16$. Later in the afternoon, around 4pm, the recorded version of the lectures was then rebroadcast world-wide with a $ttl = 127$. Changes such as these must be announced ahead of time to ensure that off-campus participants could arrange their schedules accordingly. Interestingly enough, there were more listeners during that week than at any other time. The 4pm PST

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broadcast must have fit into everyone's schedule better and remote viewers were already online from the WWW conference.

c. Audio Issues

As previously stated, since the equipment used for the MBone multicast was located inside the booth of the auditorium, it was necessary to put a wireless microphone on Dr. Hamming before each lecture. Finding the perfect location on Dr. Hamming's tie was important. Placing the microphone too high resulted in a lot of noise in the signal. Too low and it became difficult to hear him. Keeping the volume up on the TV was a good way to tell if the volume was working. The audio signal should be tested before beginning transmission. Sometimes, a weak signal just meant the battery was running down, so a supply of spare batteries was kept handy.

Dr. Hamming's lectures, with the exception of one, were just that-- lectures. Students did not ask questions and rarely challenged his ideas. A different format would have been more difficult for the researchers because the students' questions could have been heard only if Dr. Hamming took off the wireless microphone and passed it around. The exception to this format was a lecture intentionally designed to provoke interaction among the students. The lecture was titled, "Can machines think?" Dr. Hamming asked his students to come to class prepared with thought-out responses to this question. He also required the students to sit in the front two rows of the auditorium; thus, the camera work was easier to perform. In order to hear every student's response, Dr. Hamming passed around the wireless microphone. For the most part, this worked; however, Dr. Hamming, sometimes forgot that he was no longer wearing the microphone, and some of his conversation was never heard. A better alternative is to have two microphones, a lapel microphone for the speaker and a hand-held microphone that the students could pass around.

d. Miscellaneous Findings

Although the auditorium was in a brand new building, it had problems. The remote controlled blinds weren't working, so it was difficult to tape the students who were in line with the windows. Also, since the AV booth was painted white and contained

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two large windows, there was some glare in the camera signal. The author recommends the walls be painted black and the windows be covered with some black curtains to cut down the glare.

2.   Problems Encountered

During the quarter, only one major problem occurred, but, unfortunately, it lasted for a week until a team of NPS personnel finally discovered the cause. During the week of May 1-5, the transmission experienced 50 percent losses at the transmitting workstation located inside the AV booth of the auditorium. This first occurred on a Friday afternoon, when was no one was around to solve the problem. During the next lecture, there was again a packet loss of 50 percent, surprising since there were no other significant processes running on that machine. The systems administrator was contacted about the problem. Thinking the problem was local with the transmitting workstation, the author rebooted the machine. That did not fix the problem. Packet loss on the local machine usually means there are problems with the local area network (LAN). So, a previously created NPS session was opened and tested. There were no losses on that session. One theory was that there was a host on the MBone sending the 'Hamming' machine a constant message to stop sending.

A variety of experiments and network tests gave conflicting indications. Finally, the system administrator loaded a copy of "Etherview" on the "Hamming" machine. Etherview is a public-domain network visualizer program with a graphical display (Hull 91). It provides a detailed look at network traffic which finally permitted the problem to be discovered. By filtering out TCP and UDP traffic, it was discovered that the NPS mainframe (*vm1.cc.nps.navy.mil*, 131.120.50.50) was sending a constant stream of Internet Control Management Protocol (ICMP) packets to the transmitting workstation. Apparently, the mainframe had faulty code which did not understand multicast. Every time the "Hamming" machine sent a multicast packet, *vm1* would send back a "check" message provoking the 50 percent loss at the source. The difficulty happened only for streams originating within NPS with $ttl > 16$. This problem lasted for an entire week. Fortunately, it did not affect others out there wishing to transmit. The answer was not

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easy to find, even for the system administrators. Dropping the MBone tunnel that connected the faulty mainframe removed the problem.

Recommendation: have a graphical tool like Etherview continuously available for any serious multicasting. The diagnosis capabilities are essential. Other tools, such as tcpdump, also work if time is made to learn the syntax. Root permission is required to run these tools, so preparation that includes the system administrator is also necessary. The problem the researchers encountered is a good example of how volatile the MBone can be. Because the MBone is experimental, keeping in touch with the MBone community via the MBone mail list is always a good idea. There are others out there willing to help with troubleshooting. Network monitoring is a good area for future work.

3.   Feedback from Viewers

a.   *Who Watched?*

The goal of the research project was to find out if an ongoing event could take place on the MBone. Feedback via e-mail from remote participants was the only indication of whether or not the project was successful. Some people responded immediately, sometimes even during a lecture if they were experiencing difficulties-- audio not getting through, for example. Other feedback was via the *vat* name window.

On average, there were ten listeners per lecture, and sometimes as few as three and as many as 33. Of these numbers, five of the participants were almost always listening. Often, a number of remote participants would join in the session, stay for a few minutes, and then exit. Events on the MBone are similar to those of a TV station. Viewers scan through various sessions to see if there are one or two that appear interesting enough to keep them on the line. The following is a snapshot of a remote audience for the lecture held on April 25, 1995. Most of these participants remained 'tuned in' for the entire lecture, perhaps because they considered the lecture material important, the signal quality was acceptable enough for users to understand the material, and, finally, there may not have been any other events occurring at that time.

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b.   Quality of Audio and Video

Audio is the most important part of a video teleconference. Our experience has shown that audio is always a bigger challenge than video. Human cognitive abilities allow us to fill in the blanks. As stated earlier, camera work can have a serious effect on what remote participants see. However, if the camera is following Dr. Hamming walking back and forth as he lectures, it doesn't really matter if the viewer misses a frame or two. It is clear that Dr. Hamming is walking back and forth. However, if packets of audio drop out, the problem is far more serious. It is not as easy to fill in those blanks, especially if the viewer is unfamiliar with the subject area.

For the most part, the quality of the audio and video signals were good. At the beginning of the quarter there was a zero percent audio loss, and from then on a steady three percent loss appeared. For two lectures, a 30 percent audio loss was reported across the NPS campus. Nothing was reported from areas outside NPS. Without remote participant feedback, there was no way to determine exactly what was happening on the other end of the broadcast. Steady attendance leads us to believe that remote signal quality was adequate for most sections of the MBone.

c.   Suggestions

When broadcasting on a global channel, announcements should be made either in local time (if they are scheduled according to local time) or in GMT (if they are scheduled in GMT). A handy time converter exists and can be found online at *http://htbp.ecse.rpi.edu/cgi-bin/tzconvert* (Stewart 95).

There was some concern from one overseas participant about even having the capability to receive such a broadcast. How do those people who cannot effectively participate due to bandwidth limitations participate? What is the point of trying to educate

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if the students cannot hear the instructor? The idea was expressed that, until more bandwidth is made available, distance education on a global basis using the MBone will, unfortunately, remain very limited.

In response to this concern, a group from the London College known as the Multimedia Integrated Conferencing for Europe (MICE) offered to rebroadcast the lectures over a European channel only (Handley). Copies of the original lecture tapes were made and sent to MICE, which has not only been rebroadcasting the lectures, but also has been working on a collaborative plan to digitize the tapes and archive them on the World Wide Web.

Scheduling events is very important, especially if they are to be transmitted on a global channel. Events can be announced by sending a message to the MBone mailing list called *rem-conf@es.net* and also by using the online MBone Global Agenda located at *http://www.cilea.it/MBone/agenda.html*.

4. Dr. Hamming's Comments

Dr. Hamming believes that to prepare for the future, students need to forge their own style and create their own vision. "I have my feet planted in a prior generation. I want the students to question me and think for themselves," stated Hamming.

Is distance learning a door to the future of education? Dr. Hamming says "yes and no." Although there have been studies documenting the effectiveness of distance learning, Dr. Hamming feels there is something about a live human being which does not seem to get through the distance learning medium. There is an aspect of group behavior that has a different affect on a classroom full of students versus a single student "tuning in" to a lecture.

Another dubious element of distance learning is the viewing mode of the student. Watching television, for example, puts one into a passive mode of viewing. Dr. Hamming feels the same thing happens to a student learning from a computer monitor. The student learns in a more passive manner and tends not to argue or debate with the instructor. Something is lost from the learning process. Dr. Hamming is quick to note that, although he cannot say what that "something" is, distance learning is better than nothing. As long

as course requirements are met, a remote student should receive credit. It's just a matter of learning and being taught. "What you learn from others you could use to follow, what you learn for yourself you can use to lead," stated Hamming.

One of the purposes of a class is to force regular attendance; otherwise the learning is postponed. Without the actual requirement to be there, it becomes too easy to do other things at the same time or even stop listening altogether. Also, when a student is required to attend a class, there seems to be more put into it ahead of time. The student tends to mentally prepare himself for the lecture. There are fewer distractions in a classroom to hinder the learning process.

When asked if this research affected his teaching style or lecture material, Dr. Hamming said he had to make adjustments in both areas. Noting that the first lecture is always the hardest in any teaching situation, Dr. Hamming said that he was able to relax and ignore the cameras after the first couple of lectures. It did not bother him that his lectures were going out live over the Internet. He could not afford to let it. He simply adopted a "so what?" attitude.

One habit did change slightly. His normal teaching routine involves walking into the classroom, talking to one or two students and then beginning his lecture. During this research project he arrived early to each lecture to get 'wired' for audio, and would then sit quietly in the auditorium to prepare his thoughts. He also made a change in his lecture material. Because the lectures would be going out over the Internet, he eliminated portions that dealt with the military aspects of students' experiences.

It was noted that there was very little student interaction during the quarter. The author thought the students might be inhibited because of the live broadcast, but Dr. Hamming stated that little discussion is typical when the class is so large. His average class size is 60-70 students. A lack of student feedback concerning the research project prevents a clear understanding of this issue. If he could, he would limit the number of students and force more class interaction.

When asked his opinion regarding the types of courses that would work well using distance learning, he felt that it wasn't a question of a good course versus a bad one. The

question that should be asked is, "What's the alternative?" Is a lecture on art eliminated from a distance learning program because looking at the pictures over a computer screen wouldn't be as good as being there? Would those remote students have the opportunity to ever see those pictures again? For Dr. Hamming's class, a class of 30 might be better than a class of 60, but would the benefits of a smaller class outweigh the loss to students who are refused enrollment? The ideal situation would be one instructor for every student, but clearly this is unrealistic. Distance learning, though not ideal, has value.

Dr. Hamming has been completely supportive throughout this effort. He even repeated a lecture without benefit of audience when a recording mistake ruined a tape. It is difficult to imagine anyone not being challenged by Dr. Richard Hamming's ideas.

5. Things to Consider

Being on the receiving end of an MBone multicast, the author was able to make some interesting observations. First, even slow frame rate video seems to add value to the conference. The frame rates experienced with this research project were usually in the range of 0.2-5 frames per second. Even so, video still seemed to create a sense of presence and give visual clues. Second, it can be valuable to be able to do other things at the workstation while receiving a broadcast. For instance, it could be useful to look up some additional information by telnetting to the library or bringing up a page in a web browser. However, being at the desktop work space can also be a disadvantage. Distractions such as phone calls and e-mail can divert attention away from the multicast.

E. SUMMARY

This distance learning case study was delivered using the Internet's MBone. The requirements necessary to conduct this study included finding a suitable location, ensuring network connectivity, installing equipment and finding a flexible instructor to teach the course. The findings in this study proved that the MBone is a viable asset for distance learning. A number of questions were raised throughout the quarter leading to a better understanding of the MBone and the concepts of distance learning.

VI. CONCLUSIONS AND RECOMMENDATIONS

A.   RESEARCH CONCLUSIONS

The Hamming case study provided the opportunity to examine the use of the MBone as a distance learning medium for global use. This project was successful. It disproves earlier beliefs that the MBone is unable to sustain an ongoing event. The goal was to prove that the MBone could sustain an ongoing event. Of the 31 lectures, 25 went out live as scheduled. Due to a scheduling conflict with the World Wide Web conference, three lectures had to be retransmitted on a global channel, at a later time in the day. The other three lectures went out one week late because of a network problem at the transmitting site. The symptoms for this particular problem as well as the solution have been documented so that in the future, an entire week of transmitting time will not be lost.

Over the course of the quarter, there were an average of ten listeners per lecture. Some provided feedback, enabling the author to learn about the quality of the broadcast. The results of the study would be more useful if more remote participants had provided feedback. As a result, speculation is the only available tool for determining the perceived signal quality of remote participants.

The MBone uses bandwidth efficiently which makes it a strong candidate for large distributed presentations. Because the MBone utilizes the Internet, using adequate equipment and providing proper training will reduce problems associated with shared networking. This work demonstrates that effective global learning using the MBone is feasible. It also shows how commands can save on travel and training expenses for personnel.

The downside of this new technical capability is that it takes a lot of time and effort to learn and effectively use. It also takes some attention to technical details so it was important to document those lessons in passing. This is a hi-tech, experimental tool that is not well understood. As a result of this thesis, capabilities that were once thought impossible are now available.

B.   RECOMMENDATIONS FOR FUTURE WORK

The ability to use the MBone for an ongoing educational project such as distance learning is remarkable. However, as already stated, there are problems that arise when utilizing a shared network, especially one as large as the Internet. It would save time and increase usability if the nature and location of these problems could be determined as they happen. Currently, users rely on other user feedback. This system only alerts the sender of a problem, it doesn't solve it. There is a need for monitoring tools that will help determine the quality of signals received at other locations.

Another recommendation for further distance learning research using the MBone is to attempt an interactive course on a global scale, possibly using 2-3 different military commands from different parts of the United States. Better statistical information can be drawn from such a study to provide a deeper look into the audio endurance of the MBone and help find out the perceived effectiveness of the MBone as a distance learning tool.

Finally, with the ability to view audio and video over the Internet comes the desire to archive that same information. Learning how to digitize these large amounts of data and store them in the most efficient way is important. "Putting it on the Web" provides even more flexibility. It allows students to view courses at a time that is more convenient. It gives instructors an avenue for teaching more students. One can build an educational video library for media on demand at almost zero dollar cost.

APPENDIX A: MBone USER'S GUIDE

A. INTRODUCTION

This user's guide is designed to assist personnel at the Naval Postgraduate School using the Multicast Backbone (MBone) for desktop conferencing. There are no instructions here on connecting a site to the MBone. To determine if a site does support the MBone, just ask the local network support people. Information on how to connect to the MBone can be found in the *MBone Frequently Asked Questions* (Casner 93) list, or *Dan's Quick and Dirty Guide to Getting Connected to the MBone* (Mosedale 94). Section J contains a complete listing of MBone resources.

B. OVERVIEW OF THE MBone

The Multicast Backbone (MBone) originated from experiments during the 1992 Internet Engineering Task Force (IETF) conferences in San Diego and Boston in which live audio and video were transmitted around the world. The MBone currently links Unix workstations and has been called a 'virtual network' because it uses the physical Internet to support routing of Internet Protocol (IP) multicast packets. On a multicast network, a packet can be sent once from machine A and distributed to machines B, C and D without having to send the original packet three times.

C. USING THE MBone TOOLS

The startup file for the MBone tools (called .sd.tcl) contains default audio and video application addresses. To change these applications you must see your local support office. The following is a list of MBone applications available on the Unix workstations at the Naval Postgraduate School.

1. <u>Session Directory</u> (*sd*): Session Directory is the tool used to manage MBone sessions. It displays available sessions and can be used to create new ones. To use the MBone tools simply type *sd* at the shell prompt. Sessions will be announced in the session

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directory window as shown in figure 1. Clicking on a session name gives information about the session such as time and date of transmission. To participate in a session press the Open button or double-click on the session entry.
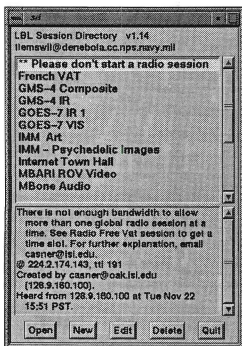

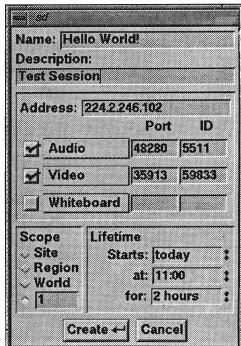

Figure 1. Session Directory (*sd*)

Figure 2. New Session Directory (*sd*) window

A new *sd* session can be created by pressing the New button. (DO NOT CREATE A NEW SESSION BEFORE READING THIS GUIDE) This causes the New session popup window to appear (see figure 2). In the Name block, fill in the title of your session. For the mandatory Description, be sure to list any important instructions and associated web pages. Do not finish the Description with a URL since *sd* will append a period and interfere with automatic launch of Netscape/Mosaic. Unused Address, Port and RTP channel ID numbers

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are automatically selected by session directory but these values can be manually changed if desired. The Scope or time-to-live range (*ttl*) determines how far your session will travel. For example a *ttl* of 16 would just go out across the NPS campus whereas a *ttl* of 127 is world-wide. DO NOT USE *TTL*=127 WITHOUT FIRST GETTING CONSENSUS WITH REM-CONF@ES.NET MAIL LIST. The Lifetime block is where you determine how long session directory will announce your session. Also, other media such as Audio, Video and Whiteboard can be associated with a session. It is important to create new sessions without error since editing a current session can create duplicates instead of replacements.

The Edit button allows you to make changes in your session. The Delete button will remove your session and Quit will exit *sd*.

The software for session directory was written at LBL by Van Jacobson and is available from *ftp://ftp.ee.lbl.gov:/conferencing/sd/* (Handley).

2. <u>Network Video (*nv*) tool</u>: Used to transmit and receive slow frame rate video. When a session that involves video communications is selected from the session directory, a control panel appears (see figure 3). It consists of a menu bar, a box to show iconic versions of active video streams, and some number of additional panels. *nv* allows you to specify various options. In most cases, the assigned defaults work just fine.

(1) Menu Bar

The Info menu lets you see the version of *nv* you have. The Grabbers menu lets you select among available grabbers. Grabbers which are supported but not available on the local host are grayed out. The Encodings menu lets you select which video encoding to use when transmitting. The Panels menu allows you to toggle on and off the presence of each additional panel. The Conference Info panel contains conference address information, as well as a place to set your name. Each of these fields may be edited - changes take affect when <Return> is pressed in a field.
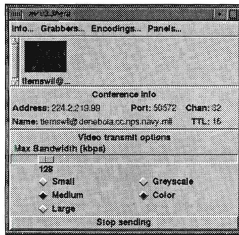
Figure 3. *nv* Tool

(2) Control Panel Options

The maximum bandwidth limit is 1024 Kbps. The default bandwidth is 128 Kbps. Frame rates of 3-5 frames per second are typical for the default bandwidth of 128 Kbps. Some systems will support higher frame rates if the bandwidth is raised or smaller images are sent.

(3) Video Icon

The Video icon box shows a small video image with a name underneath for each video stream it receives. Clicking on that video icon will display a larger video image for that source (see figure 4).

Clicking on the larger video image will display an extra control panel which allows you to adjust the Brightness and Contrast of the image (see figure 5). The brightness and contrast parameters range from 0 to 100. The defaults are set at 60 and rarely need adjustment. The display size for incoming video windows can be set to half, normal, or double the original size.

Figure 4. *nv* Larger Video Icon

The control panel also displays the source address of the sender, the video format, the incoming and displayed frame rate, the incoming bandwidth, and a running average value for network loss. Other controls include a set of size buttons, a switch to view the video as either Grayscale or Color (if color is being sent), and a button which allows you to Capture the current image into a new window.

(4) To Exit

Any window may be deleted by pressing <Ctrl-C> or <ESC>. If you delete the control panel window in this fashion, the program will exit.

The software for *nv* was written at Xerox PARC by Ron Frederick and is available from *ftp://parcftp.xerox.com:/pub/net-research/nvbin-**. (Handley)
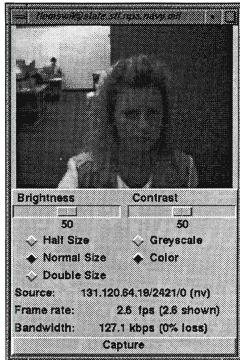
Figure 5. *nv* Control Panel

3. <u>Visual Audio Tool (*vat*) version 2.4</u>: Used for audio teleconferences. When a session that involves audio communications is selected from the session directory, the *vat* window appears. It is not necessary to speak in order to participate in a conference. In fact, the normal etiquette is to wait until the speaker has finished and has opened questions to the floor or to the Internet, before speaking. Using *vat* requires a certain amount of prudence to avoid accidental transmissions during conference sessions. The *vat* window is divided into two parts: the right has controls for the local audio and the left side displays the user names of those individuals participating in the current session (see figure 6).
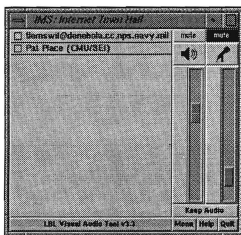
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Figure 6. *vat* window

The audio controls consist of two sliders that control the microphone and speaker. To adjust the sliders, either click at the desired position or click and drag the slide button to the desired position. Just to the left of each slider is a VU meter. A rule of thumb is to adjust the mike and speaker gain sliders so the peak readings on the meter are about 80% of full scale. Audio input has two forms: microphone and line-in mode. The microphone is normally used for desktop conferencing while the line-in mode works best for room conferencing. Above the speaker and microphone buttons is a button to mute/unmute either the mike or speaker which will mute out sound when depressed. The button will be highlighted when muting. Clicking on the microphone icon will toggle input selection to the next auxiliary input jack. Clicking on the speaker icon is an alternate way to mute. It is usually a good idea to practice getting your audio levels right with someone else remote.

The left side of the *vat* window, which lists every site currently participating in the session, will always list your site first. The participant name is displayed in a box that is highlighted whenever that site is speaking and grayed-out if the participant is no longer

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connected. This usually indicates that the site has lost connectivity or that *vat* has been aborted or stopped.

There is a box to the left of each participant name. Clicking on the box puts an 'x' in it and will cause audio from that participant to be discarded instead of played (for example, this might be used to suppress a site that is generating echoes). A small black box inside each box indicates people who have spoken recently. Names, by default, appear in the form user@host, but can be changed by the user from within the *vat* menu. At the bottom of the *vat* window are four more buttons:

(1) Keep Audio

One host can run a number of *vat* sessions. However, since most workstations have only one set of audio hardware, only one of those sessions will be able to access the microphone and speaker. If you press the Keep Audio button, the audio device will be acquired by that session and the session that previously held the audio will relinquish it. The active session will have the Keep Audio button highlighted.
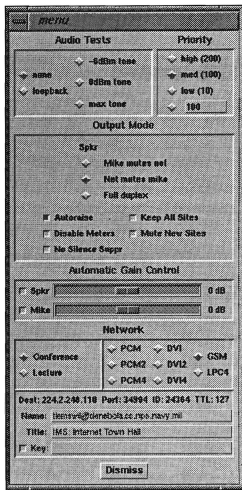

Figure 7. *vat* Menu

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(2) Menu

Clicking on the menu label at the bottom of the *vat* window will cause a panel of auxiliary controls to open (see figure 7). In general preset defaults should be used; however you have the option of adjusting these controls. The Audio Tests buttons will generate audio test tones to verify software and your audio hardware are properly configured. Loopback lets you speak into the microphone and hear your voice locally. Be careful not to cause feedback. These should never be selected during a conference. No Silence Suppress, located in Output Mode, should be selected for noninteractive sessions at the transmitting site. This may result in better quality audio by using longer playout periods. Conference mode, located in Network portion of the Menu, is recommended for interactive sessions. Lecture mode should be chosen for noninteractive sessions. The switch can be made at any time and takes effect immediately.

There are two type-in boxes at the bottom of the Menu. The one labeled Name can be used to change the session name announced to other sites. The one labeled Title can be used to change the title of your session. Go ahead and be creative! Modifying the title is an excellent way to pass messages during an audio program that is continuously originating from a single source. The Key button can be used to specify an encryption key. Since *vat* conversations are typically conducted over open IP networks there is no way to prevent eavesdropping, particularly for multicast conferences. To add some measure of privacy, *vat* allows the audio packet streams to be DES encrypted. The Dismiss button will return you back to the main *vat* window.

(3) Help. This button provides more detailed information about *vat*.

(4) Quit. Selecting this button will end the *vat* session.

The *vat* software was written by Van Jacobson and Steve McCanne of LBL, with contributed effort from others, and is available from *ftp://ftp.ee.lbl.gov:/conferencing/vat/* (Handley).

4. VIdeo Conference (*vic*): *vic* is an experimental video conferencing tool for transmitting video over an IP Multicast network. The main *vic* window provides an abbreviated summary of all sources that are actively transmitting video to the conference address (see figure 8). If no one is transmitting video to the session, the text 'No Network Sources' will be displayed.

Clicking on the Menu button in the lower right hand corner of the main *vic* window will bring up *vic* menu (see figure 9), which is composed of three subpanels: Transmission, Encoder, and Session.
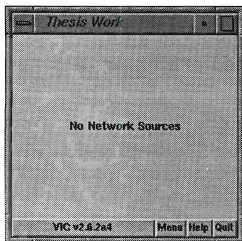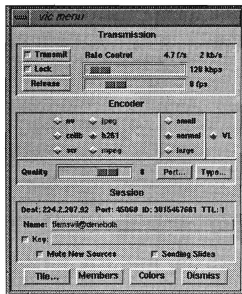

Figure 8. *vic* window

Figure 9. *vic* menu

The Transmission subpanel includes a Transmit button which opens the video capture device and begins transmission. The Lock button is designed to prevent any external agents

from automatically initiating or terminating transmission. The Release button will terminate the transmission if active and close the capture device. Adjacent to the transmission buttons are Rate Control sliders. The bit rate is limited by the top slider while the frame rate is limited by the bottom slider. The frame rate slider ranges from 1 to 30 frames/sec, while the bit-rate slider ranges from 10 to 3072 Kbps. The actual capture (and encode) rates can vary within these bounds and are displayed above the two sliders.

The Encoder subpanel contains controls for selecting the coding format, video image size, coding quality level, device ports, signal type, and device. Not all options are supported by all devices. Formats that are not supported by the underlying device (or by software compression) are grayed out and disabled. The video image size is controlled by selecting generic 'small', 'normal' and 'large' formats. If a size is not supported by the underlying hardware, the corresponding button will be disabled. The Port button selects among the analog input jacks to the capture device for example, a VideoPix has two composite inputs and an S-Video input. The Type button selects the analog video types, which is one of auto, NTSC, PAL, or SECAM. The 'auto' setting attempts to determine the signal type from the actual input.

The Session subpanel controls conference address information, some type-in boxes, and other session controls. The first line of the panel lists the numeric IP address, UDP port of the conference, the RTP source identifier, and the multicast *ttl*. The type-in box labeled Name can be used to change the RTP session name announced to other sites. The other type-in box labeled Key contains an optional session key for encryption. (Since *vic* conversations are typically conducted over open IP networks, there is no way to prevent eavesdropping, particularly for multicast conferences. Below the type-in boxes are switches for controlling session behavior. The Mute New Sources button, when selected, causes sources that transmit video to come up 'muted.'

Along the bottom of the control menu you will find a Tile button. This is a pull-down menu that allows you to specify the number of columns to use for displaying the thumbnail summaries of each active source. The default is single column. The number of columns can also be specified by typing a single digit into the main window. Also along the bottom is a

Members button that brings up a top level window with a scrollable list of all the participants in the session. This list includes participants that are not actively sending video. The Dismiss button will close the menu.

Once you have made all your selections in the menu and are ready to send, click the Transmit button. A small video image will appear in the *vic* main window (see figure 10). If other participants decide to transmit over the same session, their video images will appear in the window as well. For each video source the *vic* window will display identification text, some bit and frame rate statistics, a Mute button, a Color button, a Stats button as well as the small video image.

The Mute button, when selected, causes *vic* to ignore video from the corresponding host. In general, you want to disable any site you're not interested in to reduce processor load. The Color button controls the color disposition of the output. When enabled (by default), video is displayed in color; otherwise, it is displayed in grayscale. The Stats button brings up a top level window containing network and video coding statistics for the corresponding source. These statistics are updated in real-time once per second.
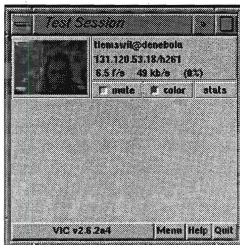

Figure 10. *vic* window with video icon

Left-mouse button clicking on a video image will open a larger viewing window of the participating source (see figure 11). Along the bottom of the window is a Size button used to set the window size and a Dismiss button to close the window. The Mode button changes the switching mode of the window. By default, the switching mode is "locked", which means that the window is locked onto the indicated video source. In "browse" mode, you can cycle through the participants by hand using the '>' and '<' keys.

vic was developed by Van Jacobson and Steve McCanne at LBL.

Figure 11. *vic* video icon

5. Shared whiteboard (*wb*) tool: Figure 12 is a picture of the whiteboard tool. Whiteboard can be used as a shared drawing surface and it can be used to export and view small PostScript files. Speakers can make their slides available as PostScript files during a conference session. The camera can be directed at the speaker while the slides are viewed via the whiteboard facility. Take some time to learn this tool. At first, set up a test session with a *ttl* of 1.

The software was written at LBL by Van Jacobson and Steve McCanne and is available from *ftp://ftp.ee.lbl.gov:/conferencing/wb/*-wb.tar.Z* (Handley)
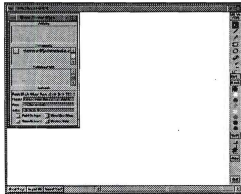
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Figure 12. Whiteboard tool (*wb*)

D. HARDWARE REQUIREMENTS

No special hardware is required to receive video on the MBone. Decoding and display are all done in software using an X-window display. The data rate is typically 25 Kbps to 128 Kbps. Transmitting video requires a workstation with a frame-capture board and camera, typically a camcorder with a video output or built-in camera. Several different boards are supported, including Sun's SunVideo, SGI's IndigoVideo, and the Sony NEWS frame capture board.

To receive audio, a machine must be audio equipped such as the SunSparc10 with an audio box, some Hewlett-Packard workstations, the SGI Indy and SGI Indigo. On most architectures, no hardware other than a microphone is required - sound I/O is via the built-in audio hardware.

E. OTHER REQUIREMENTS

1. Good lighting: Given a choice between office lighting and a desk lamp, the lamp significantly improves image quality, especially in otherwise low light conditions with inexpensive cameras.

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2. Video camera: If you will be transmitting video, a fixed focus camera that works well in your particular lighting conditions is fine for the desktop. A camcorder is more expensive, but performs better in lower light and has zoom capability. Once again, a camera isn't required to receive or display video.

F. POPULAR EVENTS

Many things are broadcast over MBone, including NASA Select's coverage of shuttle missions. The House and Senate usually broadcast audio sessions, and Radio Free Vat is a 'radio-station' where any MBone participant can sign up for spots to play music. Scheduling events is very important, especially if they are to be transmitted on a global channel. Events can be announced by sending a message to the MBone mailing list called *rem-conf@es.net* and also by using the online MBone Global Agenda located at *http://www.cilea.it/MBone/agenda.html*.

G. MAP OF THE MBONE

A small map of the MBone can be found at

ftp://parcftp.xerox.com/pub/net-research/mbone-map-small.ps

A large map can be found at

ftp://parcftp.xerox.com/pub/net-research/mbone-map-big.ps

H. NETWORK CONSIDERATIONS

Multicasting is bandwidth efficient as one packet can be received by all machines on a network. For example one audio stream received by one workstation uses the same bandwidth as the same stream being subscribed to by 15 workstations. Another good feature of the MBone is that the life of a session can be limited, for example a broadcast may be set to last 30 minutes. After that time the broadcast ends and the resources are recouped for new sessions.

Another good feature is that the packets may be limited in their transmission radius. There is a *ttl* (time to live) setting that is used to limit how far a packet might go. For example

a university might want to limit a transmission from a general student machine to campus machines only, this would be accomplished by a *ttl* setting of 16. This can happen because the *ttl* field is decreased each time the packet is sent through an mrouter. This limiting ability is important because transmissions such as video can use much of the resources of the connections between sites on the Internet. Audio usually consumes 32 or up to 64 Kbps and default video twice that at 128 Kbps. This number is based on the encoding method selected in the *vat* window. Video multicasts should have lower *ttl* setting so they do not pass through links with low bandwidth.

I. DO'S & DON'TS

There are no formal procedures for scheduling the use of the MBone, at least not yet. Management of bandwidth is a cooperative effort depending on the good behavior of the participants. Using the MBone without any regard to other users (i.e. broadcasting at high amounts of bandwidth) is not only rude but can bring a great deal of embarrassment to yourself as well as NPS. Please use common sense. If done properly, using the MBone can be fun.

Typically, discussion of the use of the MBone happens on the *rem-conf@es.net* mailing list. To subscribe to this list, send a message to *rem-conf-request@es.net*. Many events are announced by a message to rem-conf. The following are some guidelines to consider when planning an MBone session:

(1) Realize that the MBone is experimental so make sure you understand the fundamentals of the technology.

(2) Try a couple of test sessions at a *ttl* of 1. You won't bother anyone with this and you'll learn the tools and can even use a higher bandwidth (say 256 Kbps).

(3) Read the man pages for the MBone tools! They go into greater detail.

(4) Announce any session over a *ttl* of 16 ahead of time to rem-conf@es.net

(5) Don't leave your Mute button off while in *vat*. No one else will be able to talk to you! This is a frequent (and embarrassing) error made by beginners.

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(6) Check your microphone & speaker levels in *vat*. They should be at approximately 80%. You don't want to blast out remote listeners. Get confirmation on audio levels from remote listeners.

(7) If broadcasting a noninteractive session, it is a good idea to get status reports from remote sites. Coordinate volunteers and be nice to them -- they are doing you a favor.

(8) Use the diagnostic tools that come with the MBone tools. Watch packet loss as an indicator that something is wrong.

(9) There are a few diagnostic tools like tcpdump that are designed to identify network problems, e.g. bad icmp messages, igmp messages, etc. At a minimum they help to see if packets are even on the net. Take some time to learn about these tools and use them for your major broadcasts.

(10) Conceivably a remote user may somehow gain access to your workstation. The only certain way to prevent unauthorized eavesdropping is to physically cover (disconnect) the camera and physically disconnect the microphone.

J. FURTHER INFORMATION

The information contained in this guide was obtained from the following resources. For a more comprehensive understanding of the MBone and associated tools, please take a look at these.

1. MBone Provides Audio and Video Across the Internet, IEEE Computer magazine, April 1994. *ftp://taurus.cs.nps.navy.mil/pub/i31a/mbone.html*

2. Introductory description of MBone (draft) from MICE.

3. The MBone Information Web. *http://www.eit.com/techinfo/mbone/mbone.html*

4. Dan's Quick and Dirty Guide to Getting Connected to the MBone

5. Guide to MBone etiquette. *http://www.eit.com/techinfo/mbone/etiquette.html*

6. The MBone FAQ. *http://www.research.att.com/MBone-faq.html*

7. Unix Man pages on *vat*, *nv* and *vic*.

8. The MBone mailing list - subscribe to: *MBone-request@isi.edu*

K. ACCESSING THE MBone TOOLS

The MBone can only be accessed through Unix workstations at this time. Labs at the Naval Postgraduate School that currently support the MBone include:

1. Ingersoll Hall: Visualization Lab (VisLab room 148)

Any person who has a Computing Services Unix account and has received MBone training may receive execute permissions to use the MBone tools. See Larry Frazier (rm In-113) for training and more information.

2. Root Hall: Systems Technology Lab (STL room 204)

Any person with an account in this lab automatically has execute permissions to use the MBone tools. See Milena Cochran (room 204) for more information.

3. Halligan Hall: Aero Lab (room 103D)

Any person with an account in this lab automatically has execute permissions to use the MBone tools. See Tony Cricelli (room 134) for more information.

4. Melville Hall: Mechanical Engineering Lab (room 138)

Any person with an account in this lab automatically has execute permissions to use the MBone tools. The MBone tools are only available on a few machines in this lab. See Dave Marco (room 138A) for more information.

5. Spanagel Hall: Virtual Reality Lab (room 506)

Any person who has an account in this lab and has received training may receive execute permissions to use the MBone tools. See Susan Whalen (room 525B) or Rosalie Johnson (room 527B) for more information.

6. Glasgow Hall:

The MBone tools are not available in Glasgow.

L. LOGIN PROCEDURES

For information about using Unix see your local support office or take a look at the Scientific Visualization Laboratory User's Guide (Chap 2, sec 2). It can be found online at *http://www.nps.navy.mil/vislab/userdoc*

M. POINTS OF CONTACT

For User problems please check with one of the following:

1. Ingersoll:

    - Larry Frazier room 113 (x2671)

    - Mike McCann room 102B (x2752)

    - Matthew Koebbe room 102A (x3778)

2. Spanagel:

    - Rosalie Johnson room 527B (x3392)

    - Susan Whalen room 525B (x2967)

3. Root:

    - Milena Cochran room 204 (x1120)

    - James Schmidt room 205B (x3674)

4. Halligan:

    - Tony Cricelli room 134 (x2910)

5. Melville:

    - Dave Marco room 138A (x2809)

APPENDIX B: ACRONYMS

ACM   Association for Computing Machinery

AI   Artificial Intelligence

AV   Audio Visual

CAI   Computer Aided Instruction

CNET   Chief of Naval Education and Training

DFAS   Defense Finance and Accounting Service

DoD   Department of Defense

E-mail Electronic Mail

FAQ   Frequently Asked Questions

FDDI   Fiber Distributed Data Interface

FPS   Frames Per Second

FTP   File Transfer Protocol

GMT   Greenwich Mean Time

ICMP   Internet Control Management Protocol

IETF   Internet Engineering Task Force

IIRG   Information Infrastructure Research Group

IP   Internet Protocol

Kbps   Kilobits per second

LAN   Local Area Network

MBone Multicast Backbone

Mbps   Megabits per second

MICE   Multimedia Integrated Conferencing for Europe

Mrouter Multicast Router

NPS   Naval Postgraduate School

NTSC   National Television Standards Committee

NV   Network Video

ONT   Office of Naval Technology

PC	Personal Computer
SD	Session Directory
SGI	Silicon Graphics Incorporated
SIGGRAPH	Special Interest Group on Graphics
TAD	Temporary Active Duty
TCP	Transport Control Protocol
TTL	time to live
UDP	User Datagram Protocol
URL	Uniform Resource Locator
VCR	Video Cassette Recorder
WAN	Wide Area Network
WB	Whiteboard
WWW	World Wide Web
VAT	Visual Audio Tool
VIC	VIdeo Conference
VTC	Video Teleconferencing
VTT	Video Teletraining

APPENDIX C: GLOSSARY

Bandwidth. A measure of the amount of data that can be transmitted per unit of time. The greater the bandwidth, the higher the possible data transmission rate.

Broadcasting. One host sends to all hosts on the same subnet.

CU-SeeMe. A video/audio conferencing application that runs on PCS and Macintosh computers.

Data Communications. The transmission of data to and from computers and components of computer systems.

Data Rate. The amount of information that can be transmitted per unit of time.

Distance learning. Communication between an instructor and student via some form of telecommunications.

File Transfer Protocol (FTP). The standard protocol for transferring files between machines on the Internet.

Information Infrastructure Research Group.

Internet. The global collective of interconnected computer networks, typically those that communicate using TCP/IP.

Internet Control Message Protocol (ICMP).

Internet Protocol (IP). Routes data packets between networks.

Local Area Network (LAN). A communications network in which all of the components are located within several kilometers of each other and which uses high transmission speeds - generally one million bits per second or higher.

Multicast Backbone. A virtual network that provides many-to-many network delivery services for applications such as videoconferencing and audio where several hosts need to communicate simultaneously.

Multicasting. The ability of an application to send a single message to the network and have it delivered to multiple recipients at possibly different locations.

<u>Network</u>. Two or more computers connected via a communications medium, together with all communications, hardware, and software components. Alternatively, a host processor, together with its attached terminals, workstations, and communications equipment, for example, transmission media, modems, and so on.

<u>Network Video tool</u>. A tool used to transmit and receive slow frame rate video.

<u>Session Directory</u>. A tool used to manage MBone sessions.

<u>Shared whiteboard tool</u>. A shared white board drawing surface that can be used to export and view postscript files.

<u>Time To Live (<i>ttl</i>)</u>. A counter used to limit multicast packet lifetimes. A threshold that a multicast datagram needs to be forwarded onto a given tunnel.

<u>Transport Control Protocol (TCP)</u>. Provides end-to-end delivery services, reliability and error control.

<u>Unicasting</u>. One host is sending to another specific single host.

<u>User Datagram Protocol (UDP)</u>. A connectionless transport protocol that allows users to send messages without connection establishment and without any guarantee of delivery service or sequencing. UDP is simply a user interface to IP.

<u>Video Conference</u>. An experimental video conferencing tool for transmitting video over an IP Multicast network.

<u>Video teleconferencing</u>. A two-way electronic form of communications that permits two or more people in different locations to engage in face-to-face audio and visual communication. Meetings, seminars, and conferences are conducted as if all participants are in the same room.

<u>Video teletraining</u>.   The use of teleconferencing point-to-point or multi-point to provide interactive remote site training.

<u>Visual Audio Tool</u>. A tool used for audio teleconferences.

<u>World Wide Web</u>. The initiative to create a universal, hypermedia-based method of access to information. It is also a client-server based service that runs over the Internet. Also called webspace in another sense.

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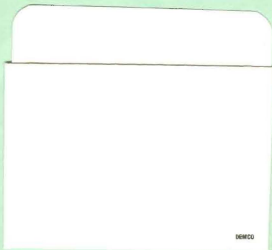
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